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2017 Kuskokwim River Chinook Salmon Run Reconstruction and 2018 Forecast

by

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and

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Alaska Department of Fish and Game **Division of Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

A maximum likelihood model was used to estimate the 2017 drainagewide run size and escapement of Kuskokwim River Chinook salmon (*Oncorhynchus tshawytscha*). Total run and escapement were estimated to be 166,863 (95% CI: 130,668–213,085) and 150,193 (95% CI: 113,998–196,415) fish, respectively. Model estimates were informed by direct observations of the 2017 escapement at 17 locations (6 weirs and 11 aerial surveys) and harvest, combined with historical observations of escapement, harvest, and mark–recapture data dating back to 1976. Acknowledging that uncertainty in the 2017 results was relatively high, model results are adequate for drawing broad conclusions about the 2017 run and escapement. The 2017 total run of Chinook salmon was the second largest since 2009, but less than 1976–2016 average of 254,737 fish. Total 2017 escapement was similar to the 1976–2016 average due to conservative management and harvest restrictions throughout the run. The drainagewide sustainable escapement goal of 65,000–120,000 was exceeded in 2017. The 2018 Kuskokwim River Chinook salmon forecast is for a range of 140,000–193,000 fish.

Key words: Chinook salmon *Oncorhynchus tshawytscha*, run reconstruction model, escapement, Kuskokwim River.

INTRODUCTION

This report describes methods used to estimate drainagewide run size and escapement of Chinook salmon (*Oncorhynchus tshawytscha*) that returned to the Kuskokwim River in western Alaska in 2017. Because it is not possible to count all Chinook salmon that return to the Kuskokwim River, estimates of annual abundance and escapement were made using a maximum likelihood model. The model (Bue et al. 2012), with subsequent revisions (Hamazaki and Liller 2015), is an extension of the approach presented by Shotwell and Adkison (2004) and was specifically developed for use in data-limited situations. The model combines information on subsistence harvest, commercial catch and effort, sport harvest, test fish harvest and catch per unit of effort at Bethel, mark–recapture estimates of inriver abundance, counts of salmon at 6 weirs, and peak aerial survey counts from 14 tributaries spread throughout the Kuskokwim River drainage (Figure 1). Each of these data sources provides an index of total abundance and some data are more informative than others. The model provides an approach to combine and weight available information about Kuskokwim River Chinook salmon abundance to arrive at a scientifically defensible estimate of total run size and escapement. Estimates produced by the model represent the most likely run size given the observed data.

The run reconstruction model was published in 2012 (Bue et al. 2012) and has quickly become an important tool to guide sustainable management of Kuskokwim River Chinook salmon fisheries. Model results contributed to a spawner-recruit analysis that was used to establish a drainagewide escapement goal of 65,000–120,000 for Kuskokwim River Chinook salmon (Hamazaki et al. 2012). The run reconstruction model has been used annually since 2013 as a postseason tool to determine if the drainagewide escapement goal was achieved. Proper application of the escapement goal requires that the model structure not change substantially relative to the model structure used to develop the escapement goal. Model results have also been used since 2012 to inform preseason management strategies for achieving escapement goals. Since 2014, a preseason forecast range has been developed based on the prior year's run size with uncertainty calculated as the recent 7-year average percent error between forecasted and actual run sizes. The rationale for this approach is based on the observation of strong serial correlation between successive years of total run size.

The current run reconstruction model has implications beyond management of Kuskokwim River Chinook salmon fisheries. Since 2016, ADF&G has been required to provide the North Pacific

Fishery Management Council (NPFMC) with a preliminary total run estimate of Kuskokwim River Chinook salmon abundance no later than October 1 of each year. The preliminary run abundance estimate is 1 component of a 3-system index (Upper Yukon, Unalakleet, and Kuskokwim rivers) of Western Alaska Chinook salmon abundance that is used by NPFMC to guide Chinook salmon bycatch thresholds in the Bering Sea pollock trawl fishery. The preliminary 2017 3-system abundance estimate was provided to the NPFMC on September 20, 2017 (Appendix A), before final escapement and subsistence harvest estimates were available. The preliminary Kuskokwim River abundance estimate was based on model output from the run reconstruction model using preliminary escapement estimates and a "best guess" of total subsistence harvest. As such, the final total run estimate was expected to change slightly from what was provided to NPFMC.

OBJECTIVE

Estimate the total run size and escapement of Kuskokwim River Chinook salmon in 2017.

METHODS

MODEL OVERVIEW

Drainagewide escapement (E_y) of Kuskokwim River Chinook salmon for year (y) is equal to the drainagewide run size (N_y) minus harvest (C_y),

$$E_y = N_y - C_y, \tag{1}$$

where C_y is the sum of harvest by subsistence, commercial, sport, and test fisheries. Each part of Equation 1 was known to different degrees. Total annual escapement was indexed by count data from weirs and aerial surveys of tributaries located throughout the lower, middle, and upper portions of the Kuskokwim River (Figure 1). Estimates of total abundance for scaling the model were derived from mark–recapture, escapement, and harvest data. Mark–recapture estimates of abundance were available at multiple spatial scales for the years 2003–2007 (Schaberg et al. 2012), 2014 (Head et al. 2017), 2015 (Smith and Liller 2017a), 2016 (Smith and Liller 2017b), and 2017 (ADF&G unpublished[1]). The 2003–2007 total run estimates reported by Schaberg et al. 2012 were used to scale the 2017 model run, and was consistent with the analysis used to establish the drainagewide escapement goal. Total annual harvests from commercial fish tickets and test fisheries were known with a high degree of confidence. Subsistence harvest was estimated from extensive postseason surveys and the estimates were incorporated into the model without error. Estimates of sport fish harvest were less precise, but the effect of a lower level of precision was assumed to be negligible given the small annual sport harvest.

Total run and escapement of Kuskokwim River Chinook salmon was estimated using a maximum likelihood model developed for data limited situations, with subsequent revisions to the model configuration (summarized in Liller and Hamazaki 2016). The model simultaneously combined abundance data from multiple sources to estimate a time series of the most likely estimates of total annual run abundance. To simplify the description of the estimation process, the methodology was divided into 3 components based on the type of data used in the model: (1)

[1] Preliminary draft: *Inriver abundance of Kuskokwim River Chinook salmon, 2017* on file with Kuskokwim Research Group, Division of Commercial Fisheries, ADF&G, Anchorage. Hereafter cited as ADF&G unpublished.

escapement, (2) commercial harvest and effort, and (3) direct estimates of total run size for model scaling.

ESCAPEMENT COUNTS

Assuming the proportion of the total annual escapement returning to each tributary is constant, the expected escapement ($\hat{e}$) in year (y) to tributary (j) observed by method (i; weir, aerial) is:

$$\hat{e}_{ijy}=E_y/k_{ij}\ , \tag{2}$$

where k_{ij} is a scaling parameter estimated by the model. The form of the negative binomial density presented in Hilborn and Mangel (1997) and Millar (2011) was used to model uncertainty in the count data. An additional parameter, typically called the overdispersion parameter ($\widehat{m}_{ij}$), was estimated to account for additional variability. The likelihood of the combined observed escapements given the estimated parameters is:

$$\mathrm{L}\left(e\middle|\hat{e},\widehat{m},\hat{k}\right)=\prod_y\ \prod_i\ \prod_j\frac{\Gamma(\widehat{m}_{ij}+e_{ijy})}{\Gamma(\widehat{m}_{ij})e_{ijy}!}\left(\frac{\hat{e}_{ijy}}{\widehat{m}_{ij}+\hat{e}_{iy}}\right)^{e_{ijy}}\left(\frac{\widehat{m}_{ij}}{\widehat{m}_{ij}+\hat{e}_{ijy}}\right)^{\widehat{m}_{ij}}. \tag{3}$$

The root mean square error (RMSE) was calculated as the standard deviation of the differences between observed and predicted values for a given escapement estimate and were used as a measure of how well model predictions of escapement matched observations.

COMMERCIAL CATCH AND EFFORT

Assuming that commercial catch and run timing are known and accurate, commercial catch effort (f_{wky}) in week (w) with net configuration (k) is:

$$\hat{f}_{wky}=-\ln\left(1-c_{wky}/\left(p_{wy}N_y\right)\right)/q_k, \tag{4}$$

where:

- c_{wky}: commercial catch at week (w) of net configuration (k),
- p_{wy}: proportion of Chinook salmon available at week (w) based on Bethel test fishery, and
- q_k: catchability coefficient of net configurations (k) (i.e., unrestricted, restricted).

Assuming the measurement error of weekly commercial catch efforts follows a lognormal distribution, the likelihood of the observed fishing effort given the estimated parameters is:

$$\mathrm{L}\left(f\middle|\hat{f},\hat{q}\right)=\prod_y\prod_w\prod_k\frac{1}{\sigma_\varepsilon\sqrt{2\pi}}\exp\left(-\frac{\left(\ln f_{wky}-\ln\hat{f}_{wky}\right)^2}{2\sigma_\varepsilon^2}\right). \tag{5}$$

The concentrated likelihood function was used to eliminate the need for estimation of variance for commercial efforts.

MODEL SCALING

Direct estimates of total run size ($\widehat{N}_y$) from the years 2003–2007 were derived from a combination of mark–recapture data, escapement estimates, extrapolation of escapement values to unmonitored areas, and harvests (Schaberg et al. 2012). Those estimates of total run and associated uncertainties were used to scale the run reconstruction model. The variance of the direct estimates (Schaberg et al. 2012) were used to represent measurement error associated with the model scalers. Assuming that measurement error follows a normal distribution, the likelihood of the observed total run given the estimated parameters is:

$$\mathrm{L}\left(N\middle|\widehat{N}\right)=\prod_{\mathrm{y}}\exp\left(-\frac{\left(N_y\text{-}\widehat{N}_y\right)^2}{2\sigma_{N_y}^2}\right). \tag{6}$$

LIKELIHOOD MODEL

The escapement, commercial harvest, and model scaling components were combined into a single likelihood model that simultaneously estimated the total run to the Kuskokwim drainage for each year:

$$\mathrm{L}(\theta|data)=\mathrm{L}\left(e\middle|\hat{e},\widehat{m},\hat{k}\right)\mathrm{L}\left(f\middle|\hat{f},\hat{q}\right)\mathrm{L}\left(N\middle|\widehat{N}\right). \tag{7}$$

Parameter estimation was performed by minimizing the negative log-likelihood of the model using R optim (R Core Team 2014) with method “L-BFGS-B” (Appendix B).

MODEL INPUTS

All model input data have been reviewed and finalized since the release of the preliminary run reconstruction estimate to NPFMC in late September 2017. In addition to using fully vetted data for the final 2017 model run, a total of 9 corrections were made to historical aerial and weir escapement data as part of a regular data review process. Three corrections to aerial survey counts were made to address transcription errors. Five corrections were new data entries of aerial survey counts from prior year data forms that had not been previously entered. All corrections corresponded to aerial flights conducted between 2002 and 2010 (Appendix C). A comparison of the model results with and without updated aerial surveys data resulted in a 150 (<0.01%) fish difference in the 2017 total run estimate. The last correction was associated with the Kwethluk River weir. The U.S. Fish and Wildlife Service (USFWS) provided a revised 2016 escapement estimate of 6,305 fish for the Kwethluk River weir on February 15, 2018; the previous estimate provided by USFWS that was used for the 2016 model run was 7,619 fish (Appendix C).

A large amount of information was available to inform the model and estimate total run and escapement in 2017. Model estimates in 2017 were informed by direct observations of harvest and escapement at 17 locations (6 weirs and 11 aerial surveys) and combined with historical estimates of escapement and harvest data back to 1976 (Appendix C). The model was scaled using 5 years of total run estimates from 2003–2007, which corresponds to years of relatively high run abundance.

SENSITIVITY TO STARTING VALUES

In preparation of the preliminary 2017 run estimate for NPFMC, model sensitivity testing was performed. The preliminary harvest estimate was varied across a range of harvest levels ranging from no harvest to 40,000 fish while keeping the escapement data unchanged. Logically, the model should produce increasingly larger estimates of total run with each increase in harvest because total harvest plus total escapement is equal to total run. The run reconstruction model did not properly converge over the range of harvest levels when the starting value for the commercial catch and effort component was set to the published starting value of -10 (Hamazaki and Liller 2015; Figure 2). Specifically, when the harvest was around 15,000 fish, the model produced erroneous results and underestimated total run. For the preliminary estimate, this issue was addressed by changing the starting value for the commercial catch and effort component from -10 to -8. Updating the starting values is not uncommon for fisheries models, but the level of sensitivity exhibited in this case was unpredictable and concerning.

Given the concern about sensitivity to starting values that was highlighted during the preliminary 2017 model run in September 2017 (Figure 2), model sensitivity was evaluated for the commercial catch and effort component of the model using finalized input data. The model was run using starting values of -6, -8, -10 and -12. There was a maximum difference of 33 fish across all starting values. A starting value of -10 was selected for the final 2017 model run because it had the same total negative log likelihood value as all other initial starting values and was consistent with the published model code (Hamazaki and Liller 2015). These results do not change the fact that the run reconstruction model has been shown to be highly sensitive to starting values. A formal evaluation of this issue is warranted.

RESULTS AND DISCUSSION

Quality of the 2017 assessment information used to inform the 2017 total run and escapement estimate was generally good. All weirs operated successfully in 2017 and weir-based estimates of tributary escapement were considered high quality. The one-time peak spawning aerial survey counts in 2017 were flown during the early portion of the standardized survey period. Surveyor comments indicated the counts were conducted prior to peak spawn and may underrepresent true spawning abundance (Aaron Tiernan, Kuskokwim Area Management Commercial Fisheries Biologist, ADF&G, Anchorage; personal communication). No commercial harvest of Kuskokwim River Chinook salmon occurred during the 2017 season. The preliminary subsistence harvest of 16,380 (95% CI: 14,937–17,823) Chinook salmon in 2017 is unlikely to change substantially and was well below the amounts reasonably necessary for subsistence uses (ANS: 67,200–109,800) as defined by the Alaska Board of Fisheries (5 AAC 01.2086).

Escapement and harvest data indicated that the 2017 run of Chinook salmon to the Kuskokwim River was similar to the 2015 and 2016 runs. A total of 13 (76%) projects reported higher escapements in 2017 compared to the 2012–2016 average, 11 (65%) projects exceeded the 2007–2016 average, and 5 (29%) projects exceeded the 1976–2016 average (Table 1). There are 10 tributaries with established escapement goals (Conitz et al. 2015), of which 9 were assessed in 2017. Of those, 1 (i.e., Holitna River aerial) was below the lower bound of the goal, 6 were within the goal range, and 2 were above the upper bound of the goal.

MODEL RESULTS

The 2017 Kuskokwim River Chinook salmon drainagewide run was estimated to be 166,863 (95% CI: 130,668–213,085) fish (Table 2; Figure 3). Coefficient of variation (CV) for the 2017 total run was estimated to be 13% (Figure 4), which is near the upper range of the 1976–2016 time-series based on the most recent model run (average: 11%, range: 5%–17%). The root mean square error (RMSE) was generally smaller for weirs compared to aerial surveys, indicating that the model fit the weir data better than aerial survey data (Figure 5). Larger overdispersion parameters for weir data compared to aerial survey data showed that the model put higher weight on weir observations (Table 3).

Estimates of total annual abundance for years 1976–2016, generated by the 2017 model run, were on average 8% (21,452 fish) larger than previously reported estimates (Table 2; Figure 6). The run reconstruction model produces updated total run and escapement estimates for all years since 1976 each time the model is updated with new information. The 2017 model run represents the most informed historical time-series of total run and escapement. Similarly, results from prior year model runs represent the best available estimates based on information that was available at that time.

Chinook salmon run sizes from 2010 to 2017 have included 8 of the 10 smallest runs on record, but run sizes have exhibited a modest increase in the past 3 years. The lowest run size on record was observed in 2013 and was followed by an annual increase in total run of about 30,000–40,000 fish in 2014 and 2015. Since 2015, total run abundance has plateaued at a level that is nearly double the 2013 run but about 34% smaller than the 1976–2016 average of 254,737 Chinook salmon. Similar to 2015 and 2016, the 2017 run was within the range of run sizes capable of supporting some fisheries and was larger than the 1986 and 2000 runs; both of which supported unrestricted subsistence harvest opportunities and were followed by periods of healthy returns (Table 2; Figure 3).

The 2017 Kuskokwim River Chinook salmon drainagewide escapement was estimated to be 150,193 (95% CI: 113,998–196,415) fish. Based on the 2017 model run, total escapement in 2017 was 10% less than the 1976–2016 average of 165,974 Chinook salmon. Total escapement in 2017 was greater than 22 of 41 (54%) prior years. Acknowledging that uncertainty in the drainagewide escapement was relatively high, the 95% confidence range of 113,998–196,415 fish provided considerable evidence that the drainagewide escapement goal of 65,000–120,000 was exceeded (Table 2; Figure 3).

UNCERTAINTY IN 2017 MODEL ESTIMATES

Model uncertainty observed in 2017 was similar to observations between 2014 and 2016, but notably higher when compared to all other years since 2000 (Figure 4). Uncertainty about any individual year model estimate is generally related to the number of index projects that operated in that year and the similarity in the information about the total run provided by each project. The 17 index projects operated in 2017 was the third largest on record (range: 2–20) over the 42 years (1976–2017) of available data, which would suggest a large amount of information to inform the model and a relatively low level of uncertainty. However, some index projects indicated the 2017 total escapement was very small, whereas others indicated the escapement was very large. The model is specifically designed to accommodate “conflicting” data from a range of index projects; however, greater differences among projects results in greater uncertainty about the actual size of the total run and escapement. To illustrate this, the entire drainagewide escapement was estimated with data from only 1 escapement project at a time (Figure 7). In 2017, estimates of drainagewide Chinook salmon escapements derived from individual weir projects ranged from 115,000–180,000 fish whereas, estimates derived from individual aerial surveys ranged from 70,000–329,000 fish (Figure 7).

Sensitivity of model results to the 2017 escapement data was explored (Figure 8). Specifically, the model was run using only weir data, only aerial survey data, with headwaters projects removed (i.e., Tatlawiksuk River weir, Takotna River weir, Salmon (Pitka) Fork aerial, Upper

Pitka Fork aerial, and Bear Creek aerial), and with removal of 1 escapement project at a time. Point estimates in all cases fell within the 95% confidence interval of the base model and confidence intervals overlapped broadly. This provides support that weirs and aerial survey data in aggregate provided a similar overall estimate of total run in 2017.

The influence of relatively large escapements to headwater tributaries on model results has been of interest in recent years. The 2017 total run estimate was not particularly sensitive to the inclusion or exclusion of 2017 escapements from the 5 headwater projects. This result was different compared to 2016 (Liller 2017) when removal of headwater escapement data resulted in a total run estimate that fell outside the 95% confidence interval of the 2016 base model. The 2017 aerial survey data indicate that escapement to the headwaters was above average, but not record high like what was observed in 2016. The headwater air survey data, however, was probably biased low in 2017 due to early survey timing combined with later than average Chinook salmon run timing. For example, the escapement objective established for the Salmon (Pitka Fork) River includes index areas 102, 103, and 104. Index area 101 was not included in the escapement objective because historically most fish have moved upstream from index area 101 prior to peak spawning. In 2017, there were 586 fish observed in index area 101, the largest on record for this index reach. In addition, the Salmon (Pitka Fork) weir (not currently used in the run reconstruction model) had a record escapement of 8,003 Chinook salmon in 2017 compared to the 6,326 fish escapement in 2016.

MODEL REVIEW CONSIDERATIONS

The run reconstruction model requires regular review and, when necessary, updates to ensure unbiased estimation of total run and escapement. Both internal and external reviews have been conducted and others are ongoing. Catalano et al. (2016) provides a detailed 5-chapter document that highlights important investigations related to the run reconstruction model and subsequent stock recruitment analyses. The Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYKSSI) has commissioned an independent peer review of the Kuskokwim Chinook Salmon run reconstruction model and mark–recapture estimates. That review is ongoing, and a final report is expected in spring 2018. ADF&G has encouraged and facilitated external reviews by providing fishery and assessment orientations, filling data requests, and providing model codes. Additionally, ADF&G has convened a collaborative Kuskokwim River Interagency Model Development Team (KRIMDT) to consider options for incorporating new abundance data and improving the model. The KRIMDT met with the AYKSSI independent review team on March 8, 2018 to discuss preliminary review findings and recommendations. Until such time that all ongoing model reviews and updates are completed, the published run reconstruction model (Liller 2017) remains the most appropriate tool for evaluating total run and escapement. A more thorough overview of the model review efforts are described in *Kuskokwim River Chinook salmon run reconstruction, 2016* (Liller 2017).

Recent fishery changes have had important implications related to the core assumptions of the run reconstruction model and model performance. Each tributary escapement project is related to the drainage escapement by a scaling factor that is estimated by the model and is assumed to be constant over time (Equation 2). Since 2014, no directed Chinook salmon fishing has been allowed during the early portion of the run, and in 2016 the Alaska Board of Fisheries formally enacted regulation to close the Chinook salmon fishery until June 11 annually. There is compelling evidence that high proportions of these early migrating fish spawn in more distant portions of the drainage (Smith and Liller 2017a, 2017b). Reduced exploitation of upriver sub-stocks is the most likely explanation for near record high escapement to headwater tributaries while overall run sizes are near record low. Due to these fishery changes, the core assumption that spawning distribution is constant over time may no longer be valid. The effect of this fishery change will be considered during the ongoing model reviews. At a minimum, this issue has resulted in less precise total run and escapement estimates (Figure 4) in recent years.

Model scaling is an important factor that influences the ability to accurately estimate total run and escapement. The model is currently scaled using 5 years of total run estimates from 2003 to 2007 (Figure 3). Run abundance in each of those 5 years was above average and included record high abundances in 2004 and 2005 (Schaberg et al. 2012). The record low run sizes beginning in 2010 may be outside the parameters on which the model has been based.

The ADF&G Division of Commercial Fisheries has completed a 4-year (2014–2017) effort to evaluate model scaling during years of low run abundance (Head et al. 2017; Smith and Liller 2017 a, 2017b; ADF&G unpublished). This effort included large-scale mark–recapture studies to estimate Chinook salmon abundance as well as visual and telemetry surveys to validate methods used for estimating escapement to unmonitored tributaries in the lower Kuskokwim River. Preliminary estimates of total run size based on mark–recapture methods are 78,600 fish (95% CI: 67,300–98,100) in 2014, 122,400 fish (95% CI: 112,000–132,600) in 2015, 127,500 fish (95% CI: 110,100–155,300) in 2016, and 133,200 fish (95% CI: 101,500–160,274) in 2017. These drainagewide total run estimates derived from recent mark–recapture data are not directly comparable to the existing model scalars because the location of the tag site changed as well as methods for estimating escapement to unmonitored tributaries downriver of the tag site. However, mark–recapture information does provide an opportunity to informally gauge model performance. A direct comparison illustrates that drainagewide estimates derived from mark–recapture data are, on average, 27% smaller (approximately 42,000 fish) compared to the estimates of total run based on the published model (Bue et al. 2012; Hamazaki and Liller 2015; Liller and Hamazaki 2016; Liller 2017; Figure 9). The 2014–2017 mark–recapture information will be used to rescale the model as part of the ongoing model review and update efforts. Discussion of the 2014–2017 mark–recapture information is intended to provide additional information about total run size and insight into run reconstruction model performance in recent years of low run abundance.

2017 Run Reconstruction Model Conclusions

- The total run of Kuskokwim River Chinook salmon was estimated to be 166,863 (95% CI: 130,668–213,085) fish (Table 2).
- Total run abundance was below the 1976–2016 average, but within a range of run sizes that could likely support subsistence harvest at levels near the lower bound of amounts necessary for subsistence (67,200–109,800) as defined by the Alaska Board of Fisheries (5 AAC 01.2086).
- The total escapement of Kuskokwim River Chinook salmon was estimated to be 150,193 (95% CI: 113,998–196,415) fish and the drainagewide sustainable escapement goal of 65,000–120,000 was exceeded (Table 2).
- Total escapement was near average (Table 2).

- Results from the 2017 mark–recapture study indicates that the true size of the 2017 run and escapement may be better represented by the lower bound of the 95% confidence range surrounding the run reconstruction model estimate (Figure 9).

2018 CHINOOK SALMON RUN FORECAST

The 2018 Kuskokwim River Chinook salmon forecast is for a range of 140,000–193,000 fish. The forecast range is equal to ±16% of the 2017 total run as presented in this report. Uncertainty in the forecast (i.e., ±16%) is based on the 2011–2017 (i.e., recent 7-year) average percent error between forecasted and actual run estimates. The forecast is not based on probability and alone provides no insight into the most likely run size within the forecasted range. Therefore, additional information, such as recent year abundance trends, stock productivity, age-class relationships, and mark–recapture information should be considered when using this forecast to plan preseason management of the 2018 Chinook salmon run.

ACKNOWLEDGEMENTS

Many fisheries technicians and biologists contributed data for estimation of the 2017 run and escapement; specifically, Jordan Head (ADF&G), Josh Clark (ADF&G), Rob Stewart (ADF&G), Ken Harper (USFWS), Aaron Webber (USFWS), Aaron Moses (USFWS) and many seasonal technicians and stakeholder volunteers. We thank the many stakeholders and professionals who have taken an interest in this model and provided constructive review of the run reconstruction model. Their advice is being considered as we work towards finalizing the model review and update process. Thanks to Gary Decossas and Bill Bechtol for providing peer review comments and edits on an earlier draft. Toshihide Hamazaki provided biometric review of this report on behalf of ADF&G.

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TABLES AND FIGURES

Table 1.–Historical and recent year observations of Kuskokwim River Chinook salmon abundance used to inform the run reconstruction model.

Method	Location	Number of years of data (1976-2017)	Historical average (1976-2016	10-yr average (2007-2016)	5-yr average (2012-2016)	2016	2017
Weir	Kwethluk	16	8,708	5,355	4,625	6,305	7,429
	Tuluksak	21	1,009	468	551	974	646
	George	19	3,426	2,371	2,086	1,663	3,685
	Kogrukluk	32	10,139	6,564	5,172	7,056	9,992
	Tatlawiksuk	18	1,631	1,383	1,623	2,494	2,156
	Takotna [a]	17	417	254	163	-	301
Aerial survey	Kwethluk [b]	11	2,183	826	1,165	-	-
	Kisaralik	24	1,143	643	628	622	-
	Tuluksak [b]	12	392	128	83	-	-
	Salmon (Aniak)	31	814	519	378	-	423
	Kipchuk	25	1,018	852	698	898	889
	Aniak	22	2,698	2,376	1,558	718	1,781
	Holokuk	16	348	196	73	100	140
	Oskawalik	21	291	136	84	47	136
	Holitna	20	1,637	784	784	1,157	676
	Cheeneetnuk	23	702	255	231	217	660
	Gagaryah	22	447	244	153	135	453
	Pitka [c]	12	221	144	-	-	234
	Bear	19	273	350	654	580	492
	Salmon (Pitka)	29	1,020	1,011	1,320	1,578	687
Harvest	Subsistence	42	68,052	52,860	25,538	30,676	16,380
	Commercial	42	19,630	2,003	169	0	0
	Sport	41	462	402	0	0	0
	Test Fishery	42	631	384	403	522	290

Note: Not all projects were operated in all years.

[a] Weir operated 1995–2013; 2017.

[b] Aerial surveys not flown since 2013 because the system is monitored by a weir.

[c] 2017 survey was the first since 2011.

Table 2.–Annual drainagewide run and escapement of Kuskokwim River Chinook salmon from the 2017 run reconstruction model.

	2017 Model run				2017 Model run			
Year	2017 Total run estimate	Lower 95% CI	Upper 95% CI	Previously published total run estimate	2017 Total esc. estimate	Lower 95% CI	Upper 95% CI	Previously published total esc. estimate
1976	240,624	183,136	316,158	233,967	150,077	92,589	225,611	143,420
1977	339,513	264,959	435,045	295,559	245,806	171,252	341,338	201,852
1978	296,890	233,737	377,106	264,325	213,418	150,265	293,634	180,853
1979	309,572	231,182	414,542	253,970	213,270	134,880	318,240	157,668
1980	321,946	234,646	441,727	300,573	224,978	137,678	344,759	203,605
1981	431,483	327,851	567,872	389,791	321,084	217,452	457,473	279,392
1982	216,810	177,788	264,397	187,354	109,809	70,787	157,396	80,353
1983	192,834	150,833	246,529	166,333	110,689	68,688	164,384	84,188
1984	218,147	165,615	287,340	188,238	128,971	76,439	198,164	99,062
1985	191,116	143,680	254,212	176,292	109,189	61,753	172,285	94,365
1986	134,021	99,779	180,016	129,168	63,409	29,167	109,404	58,556
1987	208,264	150,743	287,735	193,465	104,021	46,500	183,492	89,222
1988	255,435	229,792	283,940	207,818	127,672	102,029	156,177	80,055
1989	282,872	228,208	350,629	241,857	156,719	102,055	224,476	115,704
1990	285,000	239,652	338,929	264,802	120,814	75,466	174,743	100,614
1991	231,044	191,624	278,573	218,705	117,896	78,476	165,425	105,589
1992	301,015	249,967	362,487	284,846	169,742	118,694	231,214	153,573
1993	308,195	244,259	388,866	269,305	208,684	144,748	289,355	169,816
1994	434,224	323,882	582,157	365,246	311,594	201,252	459,527	242,616
1995	414,839	332,083	518,217	360,513	279,921	197,165	383,299	225,595
1996	365,296	276,058	483,382	302,603	259,785	170,547	377,871	197,092
1997	361,830	277,398	471,961	303,189	270,449	186,017	380,580	211,247
1998	208,267	156,391	277,350	213,873	108,051	56,175	177,134	113,627
1999	181,869	143,736	230,117	189,939	104,039	65,906	152,287	112,082
2000	146,741	123,523	174,324	136,618	78,508	55,290	106,091	65,180
2001	252,621	202,456	315,218	223,707	174,146	123,981	236,743	145,232
2002	252,026	210,598	301,602	246,296	170,365	128,937	219,941	164,635
2003	276,929	235,284	325,945	248,789	208,827	167,182	257,843	180,687
2004	411,977	346,182	490,277	388,136	311,336	245,541	389,636	287,178
2005	390,720	334,098	456,938	366,601	299,717	243,095	365,935	275,598
2006	335,004	279,709	401,231	307,662	241,346	186,051	307,573	214,004
2007	282,204	244,267	326,032	273,060	184,087	146,150	227,915	174,943
2008	242,499	208,682	281,796	237,074	134,403	100,586	173,700	128,978
2009	212,493	179,154	252,037	204,747	126,224	92,885	165,768	118,478
2010	124,463	109,168	141,902	118,507	55,029	39,734	72,468	49,073
2011	131,892	114,071	152,497	133,059	67,861	50,040	88,466	72,097
2012	99,607	78,303	126,708	99,807	76,115	54,811	103,216	76,074
2013	90,603	79,318	103,494	94,166	43,115	31,830	56,006	47,315
2014	131,005	99,773	172,014	135,749	119,239	88,007	160,248	123,987
2015	163,543	123,733	216,160	172,055	146,939	107,129	199,556	155,464
2016	168,797	129,729	219,629	176,916	137,582	98,514	188,414	145,718
2017	166,863	130,668	213,085		150,193	113,998	196,415	
Average (1976-2016)	254,737	(Diff. = 21,452 or 8%)		233,285	165,974	(Diff. = 21,467 or 14%)		144,507

Note: The run reconstruction model produces estimates for all years every time the model is updated with new information. Previously published estimates of total run and escapement associated with prior year model runs are shown for reference.

Table 3.–Parameter estimates derived from the 2017 run reconstruction model.

	Parameter estimate (*k*)	95% Bound Lower	95% Bound Upper	Overdispersion parameter (*m*)
Weir projects (*k*)				
Kwethluk weir	19.30	15.06	24.74	7.50
Tuluksak weir	178.45	139.44	228.37	6.43
George weir	43.78	34.73	55.19	10.78
Kogrukluk weir	16.34	13.28	20.10	10.07
Tatlawiksuk weir	83.47	67.02	103.96	15.86
Takotna weir	386.88	301.90	495.78	8.59
			Average	9.87
Aerial survey (*k*)				
Kwethluk River	87.57	59.00	129.98	2.73
Kisaralik River	159.18	111.56	227.11	1.64
Tuluksak River	486.25	338.86	697.75	3.40
Salmon (Aniak River)	231.16	177.43	301.18	3.08
Kipchuk River	170.65	132.62	219.59	4.53
Aniak River	65.88	51.24	84.70	5.42
Holokuk River	499.96	327.17	763.99	1.61
Oskawalik River	661.60	464.85	941.63	2.02
Holitna River	107.79	81.41	142.72	4.49
Cheeneetnuk River	248.08	185.83	331.17	3.42
Gagaryah River	404.36	312.70	522.89	4.47
Pitka Fork	751.97	570.27	991.56	7.12
Bear River	667.99	488.17	914.03	3.35
Salmon(Pitka Fork)	151.10	117.78	193.85	4.17
			Average	3.67
Catchability (*q*)				
Unrestricted	7.13E-05	5.73E-05	8.88E-05	
Restricted (1)	1.30E-05	9.89E-06	1.71E-05	
Restricted (2)	4.05E-05	3.31E-05	4.96E-05	

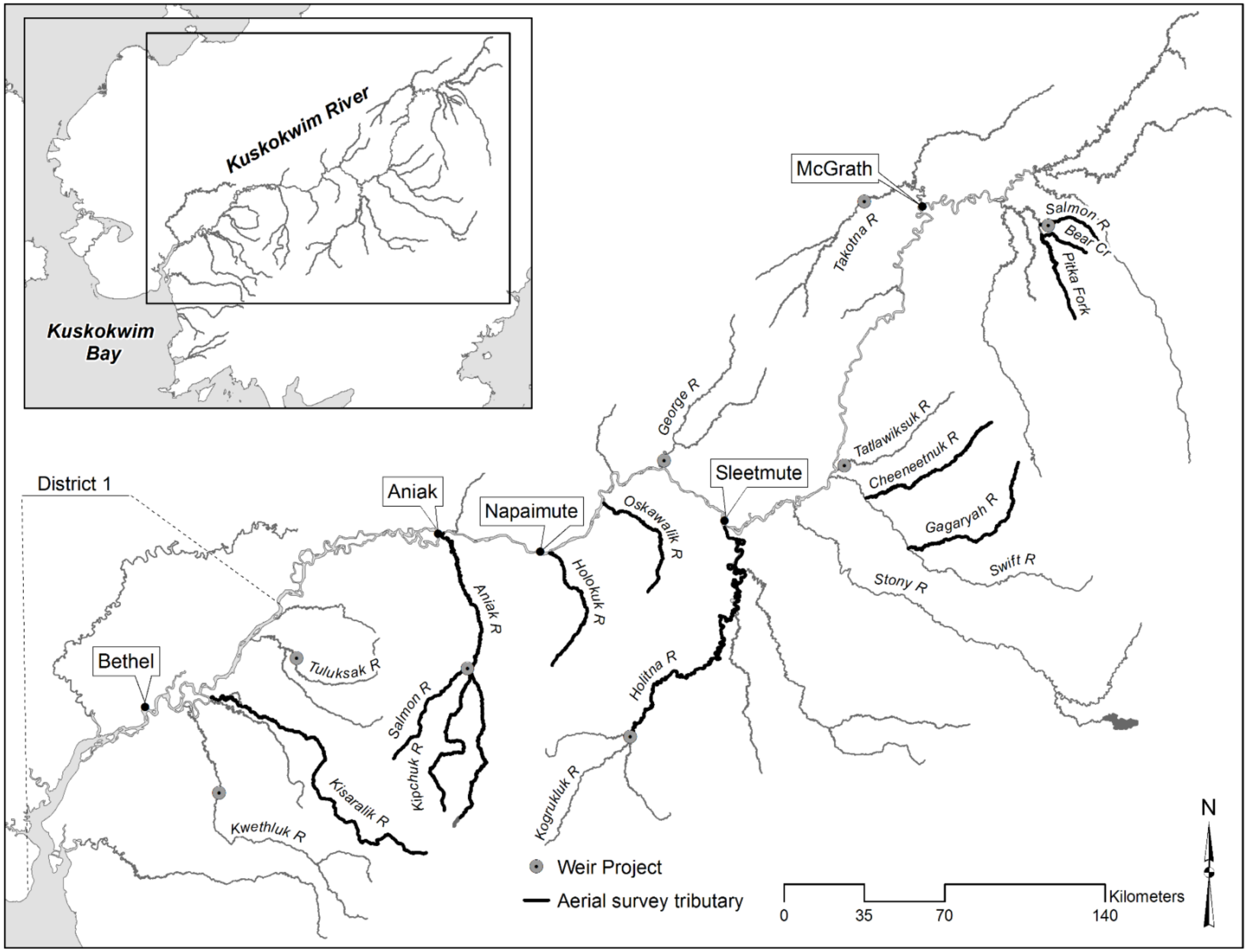

Figure 1.–Kuskokwim River tributaries where Chinook salmon escapement was monitored in 2017.

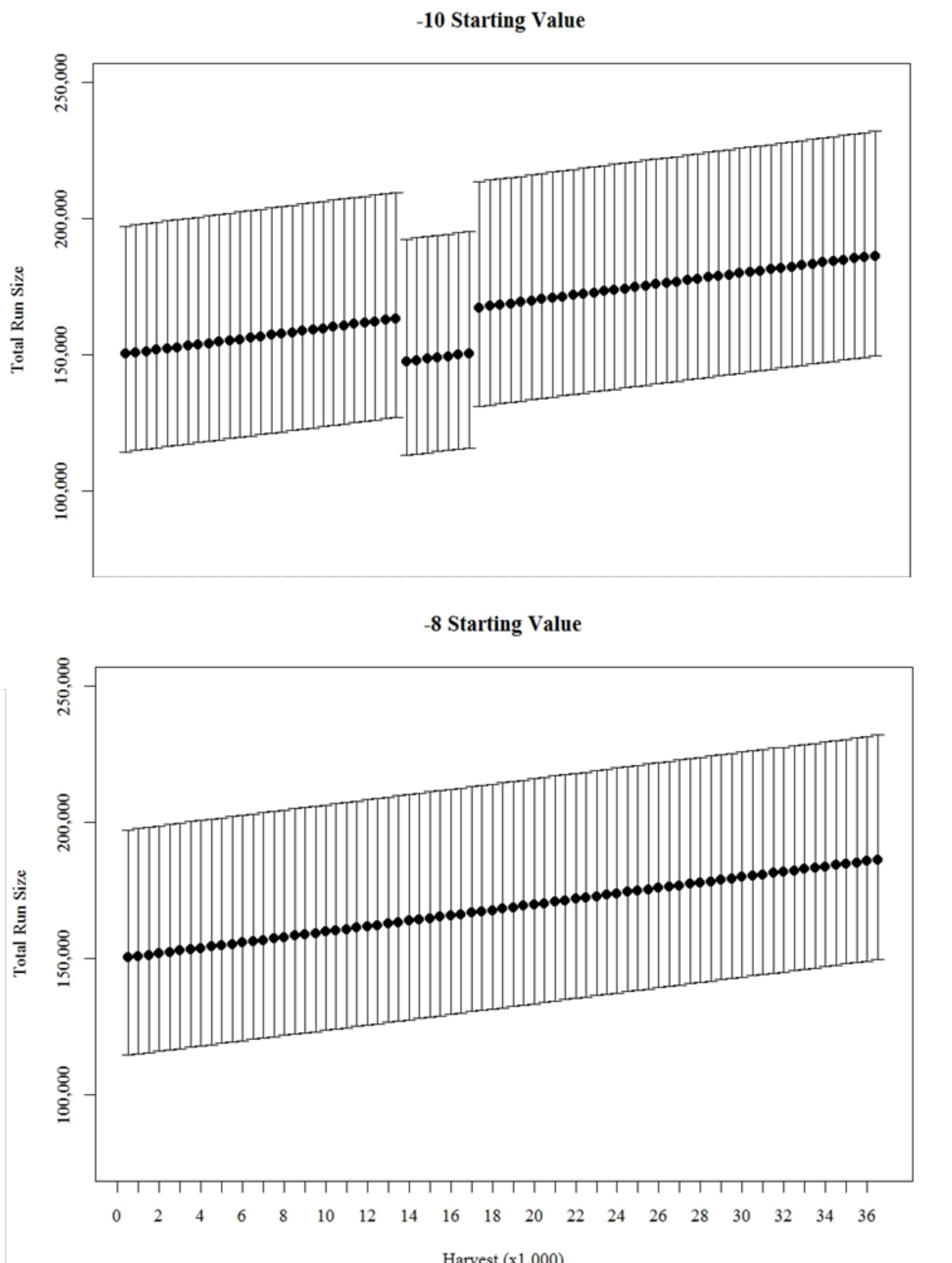

Figure 2.–Preliminary 2017 estimates of total abundance and 95% confidence intervals across a range of harvest values using a starting value of -10 (top) and -8 (bottom) for the catch and effort component.

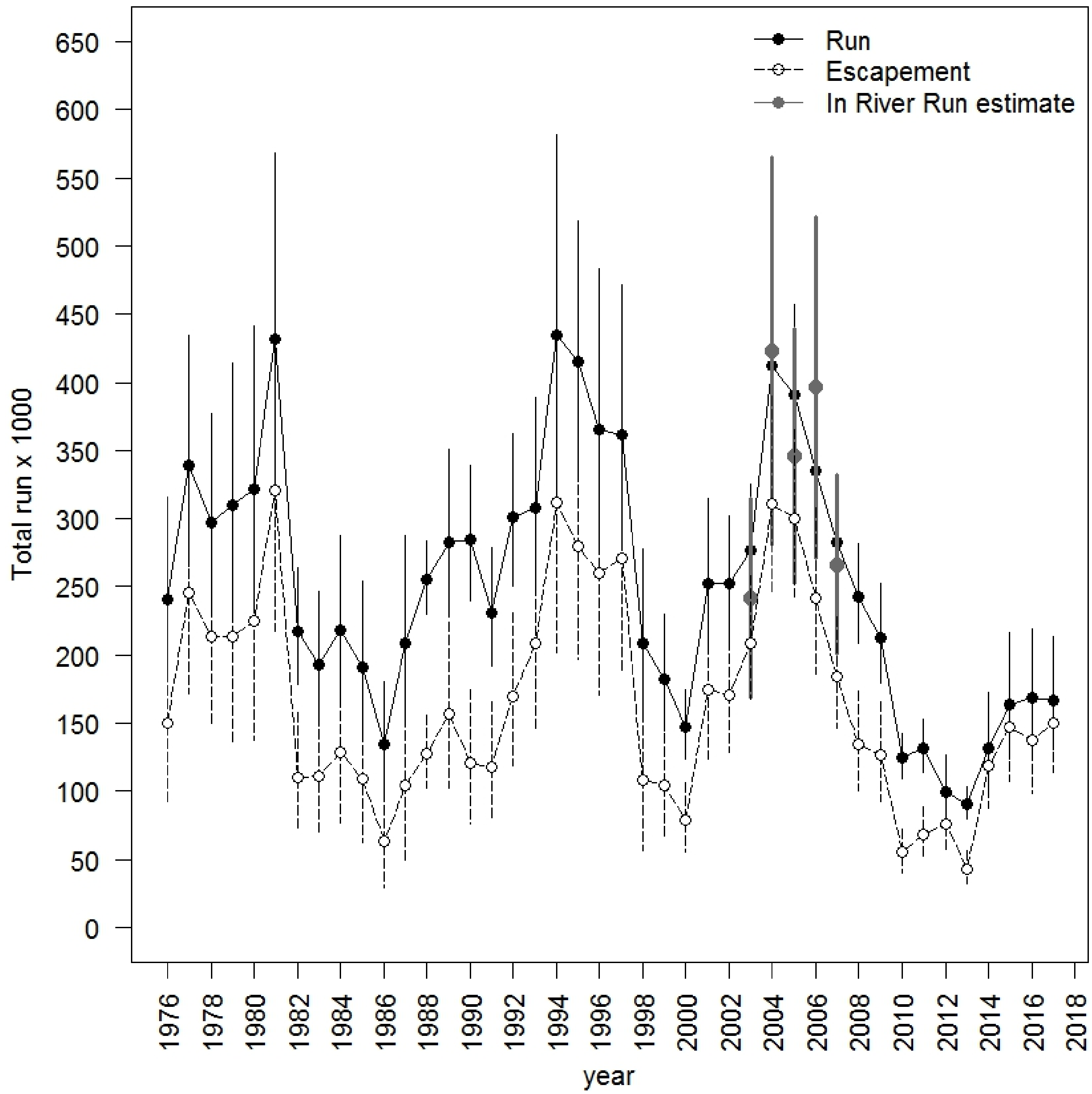

Figure 3.–Annual run (black) and escapement (white) estimates with 95% confidence intervals estimated from the 2017 run reconstruction model.

Note: Gray dots are the independent observed drainagewide run size and 95% confidence intervals for years 2003–2007 used to scale the model.

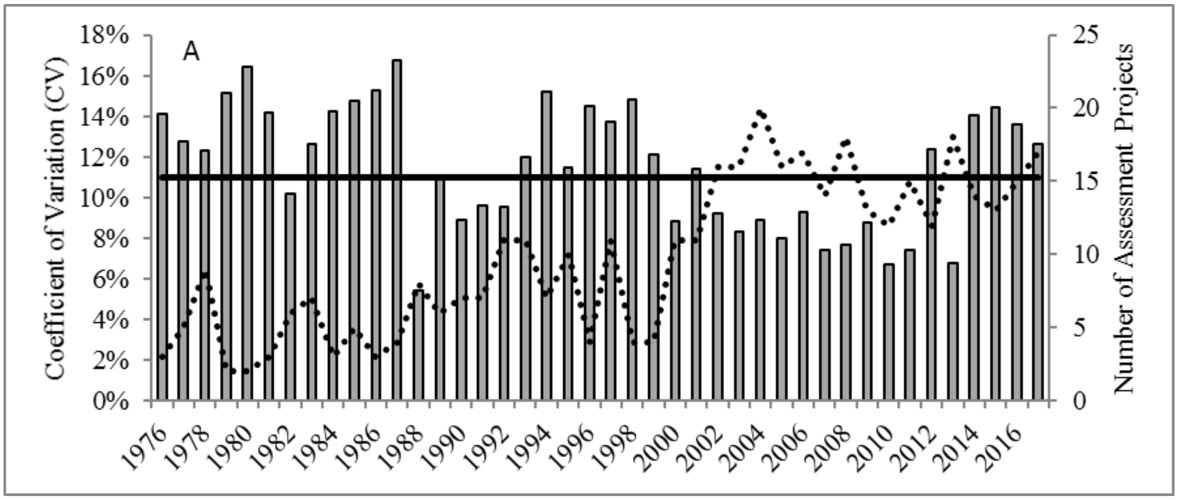

Figure 4.–Annual uncertainty (coefficient of variation; gray bars) of the run reconstruction model estimate of total run size and the number of assessment projects (dotted black line) used to inform the model in each year.

Note: The solid black line is the average coefficient of variation (11%) across years 1976–2016.

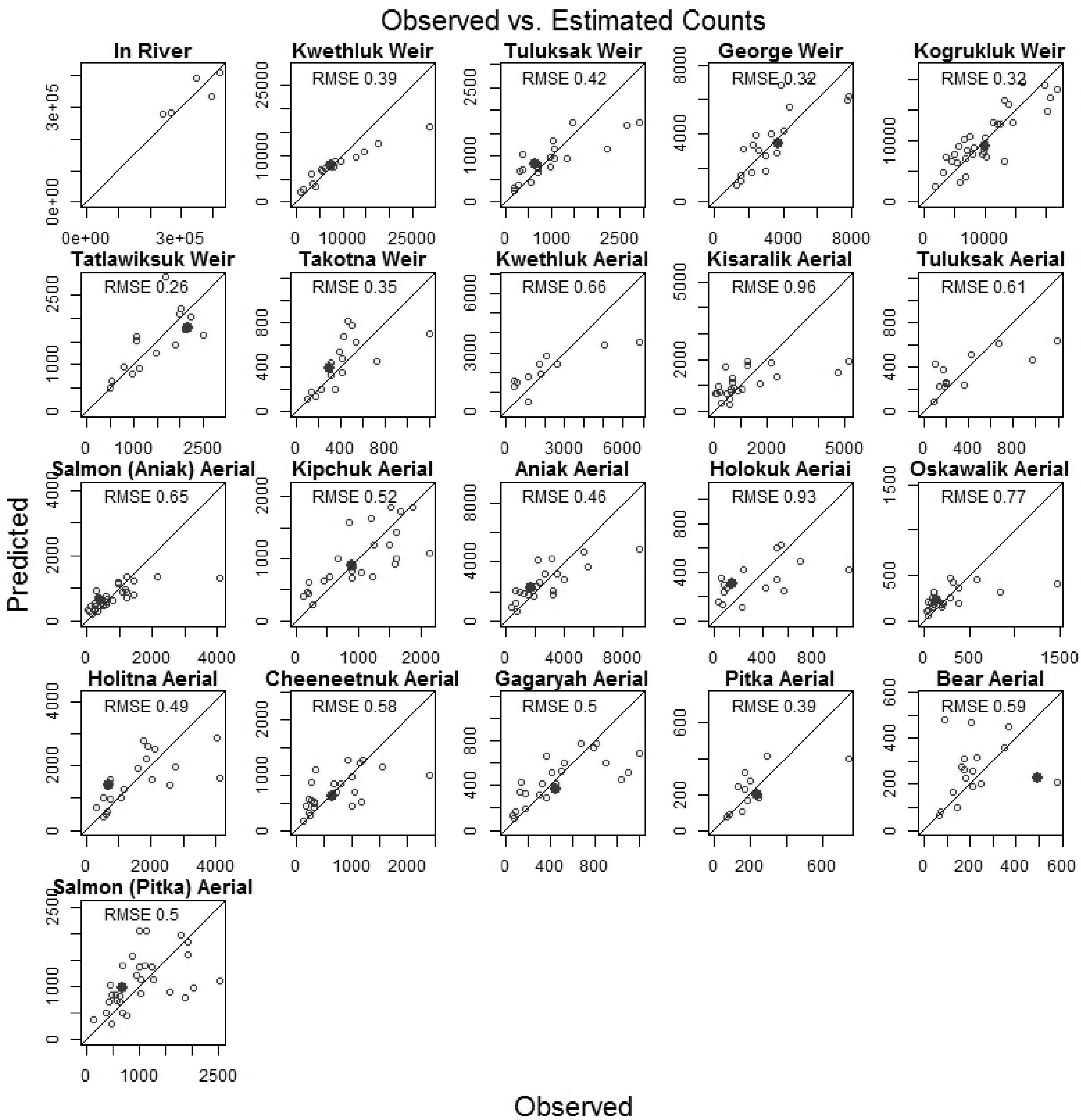

Figure 5.–Observed versus model estimated escapement counts.

Note: The diagonal line within each subplot represent the 1:1 line, which is the point at which observed and estimated escapements are equal. Hollow dots are the prior year observations and solid dots are the 2017 observations. Dots that fall below the 1:1 line indicate that the observed counts are higher than the model estimates, and the opposite is also true. The top left subplot titled “In River” is the 2003–2007 total run estimates used to scale the model.

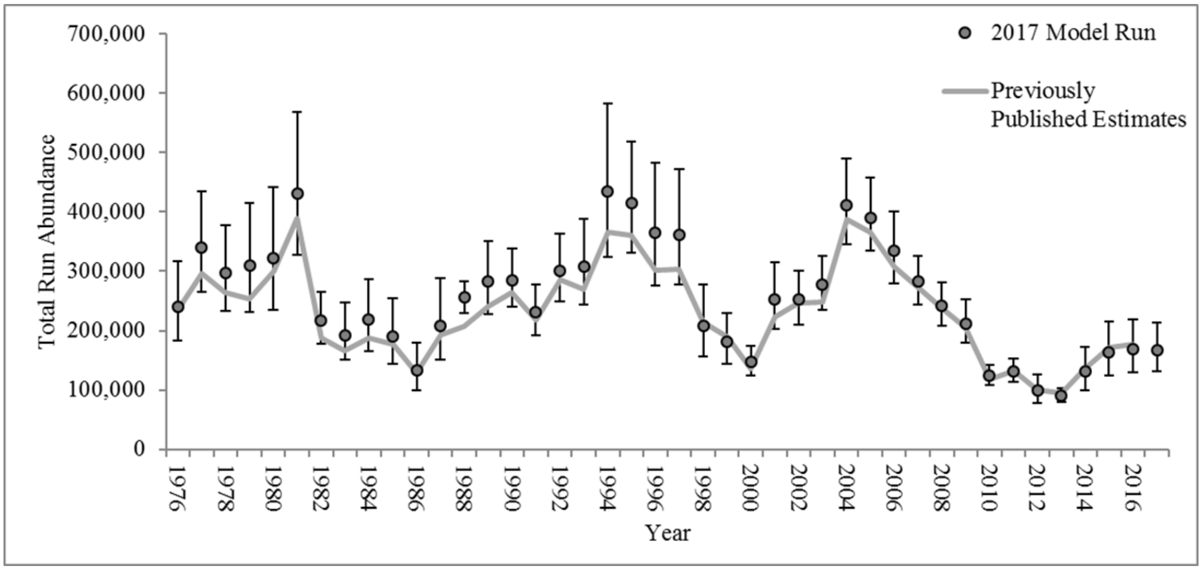

Figure 6.–Comparison of 2017 model run reconstruction estimates of total Kuskokwim River Chinook salmon run size (95% confidence intervals) and previously published results reported by Bue et al. (2012), Hamazaki and Liller (2015), Liller and Hamazaki (2016), and Liller (2017).

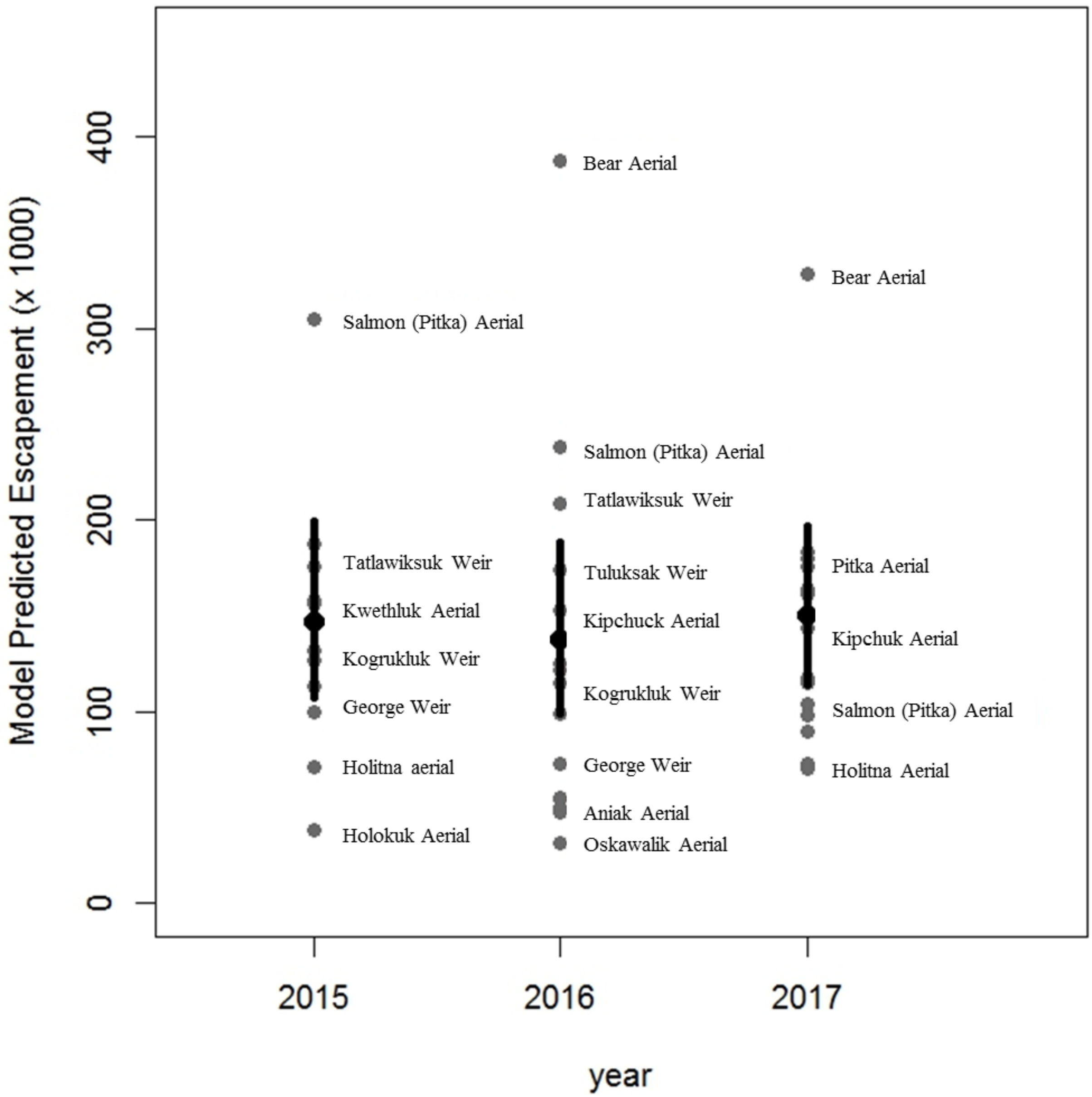

Figure 7.–Range of drainagewide escapement estimates produced by the model based on each individual escapement project.

Note: Gray dots are individual project estimates of total run based on the model estimated scaling factor. Black dots and lines shows the model derived drainagewide escapement and 95% confidence interval after simultaneously combining the information from all escapement monitoring projects. The more similar the project estimates the tighter the confidence range around the drainagewide estimate. 2015, 2016, and 2017 are shown to provide context.

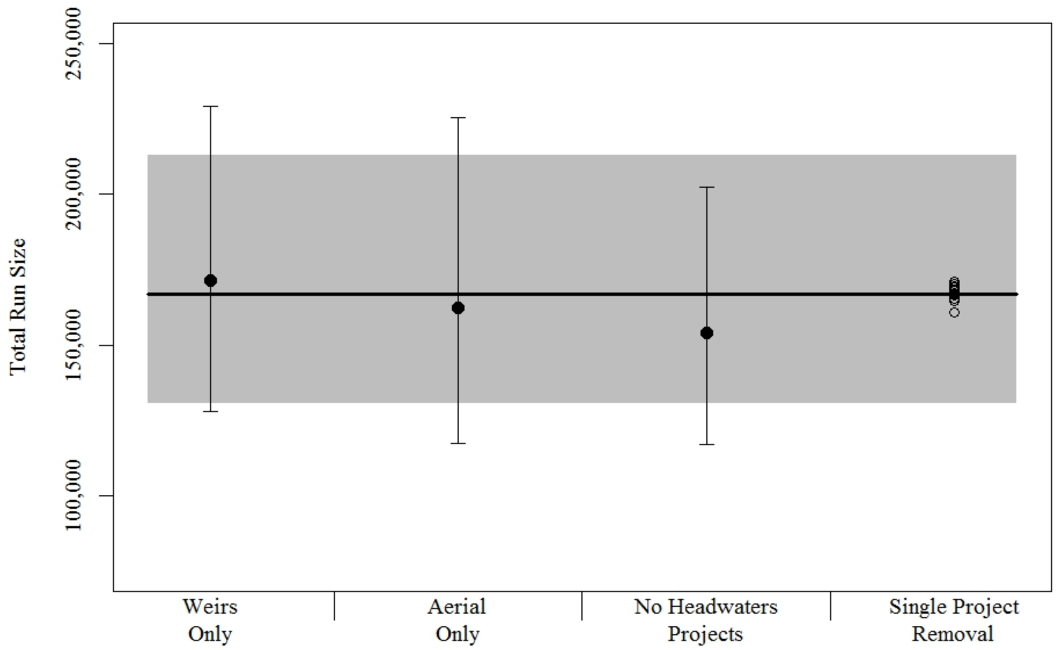

Figure 8.–Sensitivity of 2017 Chinook salmon total run size estimates using weir data only, aerial survey data only, exclusion of headwaters project data, and removal of single escapement monitoring projects (hollow dots).

Note: The solid black line is the point estimate of the ADF&G base model and the grey shaded area is the 95% confidence interval. Alternative estimates (black dots) and 95% confidence intervals are shown for comparison. The amount of overlap with the grey shaded area indicates the degree of similarity between estimates.

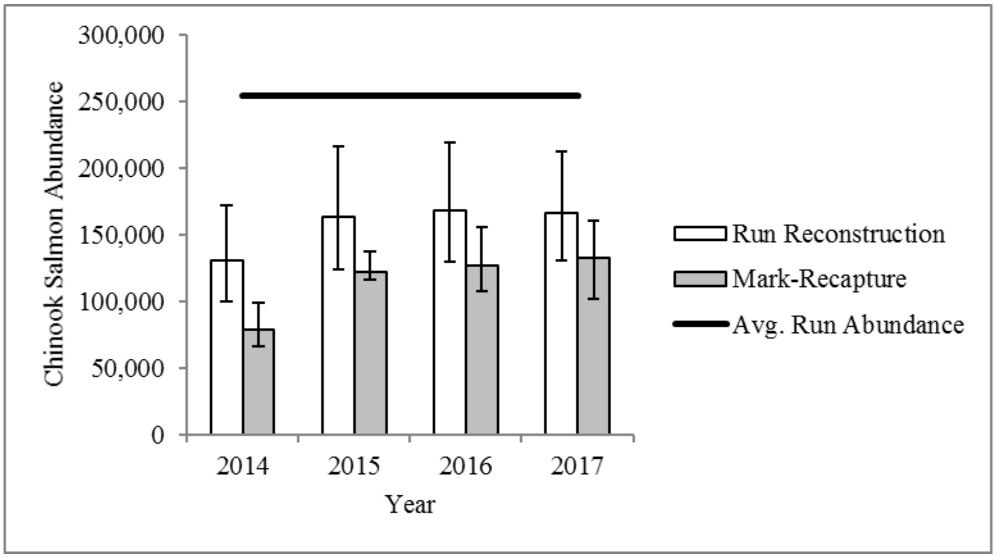

Figure 9.–Estimates of total run size of Kuskokwim Chinook salmon using the 2017 model run and preliminary mark–recapture methods, 2014–2017.

APPENDIX A: 2017 NPFMC 3-SYSTEM INDEX LETTER

Appendix A1.–2017 NPFRMC 3-system index letter.

B4 Chinook Index Letter to NMFS
October 2017

THE STATE *of* ALASKA

GOVERNOR BILL WALKER

Department of Fish and Game

DIVISION OF COMMERCIAL FISHERIES
Headquarters Office

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September 20, 2017

Dr. James Balsiger, Administrator
NOAA Fisheries, Alaska Region
PO Box 21668
Juneau, Alaska 99802-1668

Dear Dr. Balsiger:

In April 2015, the North Pacific Fishery Management Council (Council) adopted an action that lowers Chinook salmon bycatch caps in the Bering Sea pollock fishery when Chinook salmon abundance in Western Alaska is at historically low levels.[1] The Council's action identifies historically low Western Alaskan Chinook salmon abundance using a 3-system index of in-river adult Chinook salmon run sizes from the Unalakleet, Upper Yukon, and Kuskokwim rivers combined at or below the threshold level of 250,000 fish. The Council's action also specified a process by which the Alaska Department of Fish and Game would provide postseason abundance estimates to the National Marine Fisheries Service (NMFS) by October 1, following the salmon season each year, to determine if the combined adult Chinook salmon abundance in the indexed systems falls at or below the threshold level of 250,000 fish. The performance standard and hard cap applicable to the Bering Sea pollock fishery would be lowered in the year following the year in which the index was ≤250,000 Chinook salmon.

Postseason run size estimates include all available escapement and commercial harvest data, and estimates of all other harvest in each system. Detailed information on methods and trend patterns in these assessments can be found in the Council's public review analysis.[2] As noted in the public review analysis, the primary difference between postseason run size estimates and final run size data is that the subsistence harvest estimate is based upon manager's expectation of subsistence harvest rather than an estimate based on survey data. Given the nature of subsistence use, Chinook salmon subsistence harvest estimates for Upper Yukon, Kuskokwim, and Unalakleet rivers are generally stable in years of adequate run size and no fishery restrictions. In years of restrictions, subsistence harvest can be expected to be somewhat lower than typical harvest, depending on the severity of the restrictions. Because the majority of the run in low run abundance years is realized as escapement, postseason estimates are a good

[1] https://npfmc.legistar.com/LegislationDetail.aspx?ID=2237783&GUID=89E4DA9C-19B8-4BDE-8643-B19D68DD9EE3

[2] Public Review draft Environmental Assessment/ Regulatory Impact Review/ Initial Regulatory Flexibility Analysis for Proposed Amendment to the Fishery Management Plan for Bering Sea Aleutian Islands Groundfish Bering Sea Chinook and Chum salmon bycatch management measures, March 2015.

surrogate for finalized run estimates. **Methods and analysis used to estimate the postseason run size for the Unalakleet, Upper Yukon, and Kuskokwim river systems have not changed and are consistent with what is outlined in the Council's public review analysis.** As required by NMFS, changes to run reconstruction methods used in the assessment of the 3-system index would first need to be evaluated and approved through the Council process. Despite using consistent methods outlined in the public review analysis, Department staff continually work to improve assessment data, and it is anticipated that an amendment to the Kuskokwim River run reconstruction may be available for Council consideration in April or June, 2018. At that time, any proposed modifications to the current methods will be presented to the SSC and Council to determine if revisions to the run assessment methods should be incorporated into the 3-system index estimate.

2017 Postseason Chinook Salmon Run Size Estimates

Unalakleet River

Preliminary Chinook salmon escapement in the Unalakleet River was 3,978 fish, measured by escapement projects on the North River tributary and mainstem Unalakleet River. Although the North River escapement counting project was impaired by high water, this occurred after the Chinook salmon run had passed, and the observed escapement is considered a reliable measure of the total Chinook salmon escapement. Harvest of Unalakleet River Chinook salmon included 327 commercially caught fish and approximately 350 subsistence caught fish. The subsistence catch was estimated based on harvests in recent years where similar fishing restrictions were enacted. The total **Unalakleet River postseason run size estimate is 4,655**.

Upper Yukon River

The entire escapement of the Upper Yukon, or Canadian-origin, stock group into Canada is assessed by a sonar project at Eagle, AK. The 2017 preliminary sonar estimate is 73,268 fish. Although minor subsistence harvest restrictions were enacted this year, overall far more subsistence opportunity was available in 2017 compared to recent years. Information from subsistence fishermen indicates subsistence harvest was similar to years without fishing restrictions, which averages 30,000 Upper Yukon Chinook salmon according to rigorous subsistence harvest surveys conducted in the fall/winter annually. Although a small number of Chinook salmon were caught and sold commercially during the fall season, given the timing of harvest, these fish are not believed to be Upper Yukon origin Chinook salmon, which primarily migrate through the river early in the summer. The estimated sonar border passage combined with the estimated harvest results in a total **Upper Yukon postseason run estimate of 103,268**. This postseason Upper Yukon run size estimate is corroborated by inseason forecasting using sonar in the lower river and genetic stock composition information that indicated approximately 105,000 Upper Yukon Chinook salmon passed the lower Yukon River sonar site. Furthermore, this total run estimate is also corroborated by preseason forecasts using juvenile Chinook salmon information from the Northern Bering Sea that predicted 93,000–134,000 fish would return in 2017.

Kuskokwim River

Total run in the Kuskokwim River is estimated using a maximum likelihood model published in 2012 (see public review analysis and referenced documents). Model estimates were informed by direct observations of the 2017 escapement at 17 locations combined with historical observations of escapement, harvest, and commercial fishing effort since 1976. Though lower river inseason run assessment overwhelmingly suggested poor run abundance, observed drainage-wide escapements indicated a higher total Chinook salmon return and an improvement upon the recent years' escapements.

Of the escapement assessment projects operated in 2017, 87% reported higher escapements compared to the recent five-year average, 67% exceeded their recent ten-year average, and 33% exceeded their long-term average. No commercial or sport fishery harvest of Kuskokwim River Chinook salmon occurred during the 2017 season. A total of 290 and 83 fish were harvested from the Bethel Test Fishery and Aniak Test fishery, respectively, which were donated for subsistence use. Significant restrictions were placed on subsistence harvest in 2017. A preliminary subsistence harvest estimate of 15,000 fish was generated using the best available inseason harvest data as well as input from fisheries managers, assessment biologists and stakeholders. The postseason total run estimate using these data inputs into the published run reconstruction model, and all published starting values, is 148,848 fish. However, biometric staff recommended changing the starting value for the commercial catch and effort component of the model from -10 to -8 to ensure that the model would properly converge across all ranges of likely harvest. The run reconstruction with the -8 starting value, which is what is recommended for proper model convergence, yields a **Kuskokwim River postseason run size of 165,102**.

Given the sum of the postseason run estimates from Unalakleet, Upper Yukon and Kuskokwim rivers, the 3-system index is 273,025 Chinook salmon. It should be noted that if the convergence problems with the Kuskokwim run reconstruction model were ignored and the -10 starting value were used for the commercial harvest and effort component of the model, the sum of the three systems would be 256,771.

Sincerely,

Scott Kelley
Commercial Fisheries Division Director

cc: Glenn Merrill, NMFS AKR

APPENDIX B: 2017 R-CODE WITH ANNOTATIONS

```
#################################################################################
# 1.0 Initialize working Environment
#################################################################################
rm(list=ls(all=TRUE))
# Enter the name of data file
data_file <- 'Kusko_RR_Input_March_10_2016.csv'
kusko.data <- read.csv(data_file,header=T, na.string='')
#################################################################################
# 2.2 Test fishery: Estimate run proportion of 1976-1983
#################################################################################
# Extract testfish data
testf<-kusko.data[substr(names(kusko.data),1,3)=='rpw']
# combine week 8, 9 and 10 and drop
testf[,8] <- testf[,8]+testf[,9]+testf[,10]
testf <- testf[,-(9:10)]
# Replace NA to mean proporion for each week
for (i in 1:dim(testf)[2]) {
  testf[is.na(testf[i]),i] <- colMeans(testf,na.rm=T)[i]
}
#################################################################################
# 2.3 Rearrange fishing effort and harvest data catch 0 to NA
#################################################################################
# Extract weekly commercial effort data
ceff <-kusko.data[substr(names(kusko.data),1,3)=='cew']
# combine week 8, 9 and drop
ceff[,6] <- ceff[,6]+ceff[,7]
ceff <- ceff[,-7]
# replace 0 to NA
ceff[ceff == 0] <- NA
# Extract weekly commercial catch data
ccat <-kusko.data[substr(names(kusko.data),1,3)=='chw']
# combine week 8, 9 and drop
```

```
ccat[,6] <- ccat[,6]+ccat[,7]
ccat <- ccat[,-7]
# replace 0 to NA
ccat[ccat == 0] <- NA
# Extract weekly commercial est data
creg <-kusko.data[substr(names(kusko.data),1,3)=='cfw']
# combine week 8, 9 and drop
creg[,6] <- pmax(creg[,6],creg[,7])
creg <- creg[,-7]
##############################################################################
# 2.4 Recalculate Inriver data
##############################################################################
# Extract Inriver data
inr <-kusko.data[substr(names(kusko.data),1,3)=='In.']
# Calculate CV
inr$cv <- inr$In.river.sd/inr$In.river
##############################################################################
# 2.5 Calculate Others
##############################################################################
tcatch <- rowSums(kusko.data[substr(names(kusko.data),1,2)=='H.'],dims = 1,na.rm=T)
# Extract escapement data
esc <- kusko.data[substr(names(kusko.data),1,2)=='w.'|substr(names(kusko.data),1,2)=='a.']
t.esc <- kusko.data$In.river - tcatch
# Calculate observed minimum escapement
minesc <- rowSums(esc, na.rm=T, dims = 1)
# Calculate observed minimum run
minrun <- rowSums(cbind(tcatch,esc), na.rm=T, dims = 1)
ny <- length(kusko.data[,1])
##############################################################################
# 2.4 Construct dataset used for likelihood modeling
##############################################################################
kusko.like.data <- as.matrix(cbind(tcatch,inr,esc,testf[3:8],ccat,ceff,creg))

nb.likelihood <- function(theta,likedat,ny){
### Total run  ###################################################################
```

```
	totrun <- exp(theta[1:ny])
### Weir slope parameters ######################################################
	w.kwe <- exp(theta[ny+1])
	w.tul <- exp(theta[ny+2])
	w.geo <- exp(theta[ny+3])
	w.kog <- exp(theta[ny+4])
	w.tat <- exp(theta[ny+5])
	w.tak <- exp(theta[ny+6])
### Aerial slope parameters #####################################################
	a.kwe <- exp(theta[ny+7])
	a.kis <- exp(theta[ny+8])
	a.tul <- exp(theta[ny+9])
	a.sla <- exp(theta[ny+10])
	a.kip <- exp(theta[ny+11])
	a.ank <- exp(theta[ny+12])
	a.hlk <- exp(theta[ny+13])
	a.osk <- exp(theta[ny+14])
	a.hlt <- exp(theta[ny+15])
	a.che <- exp(theta[ny+16])
	a.gag <- exp(theta[ny+17])
	a.pit <- exp(theta[ny+18])
	a.ber <- exp(theta[ny+19])
	a.slp <- exp(theta[ny+20])

### Catch coefficient parameters #################################################
# catchability coefficient Unrestricted
	q1 <- exp(theta[ny+21])
# catchability coefficient Restricted
	q2 <- exp(theta[ny+22])
# catchability coefficient Center Core monofilament
	q3 <- exp(theta[ny+23])
### Overdispersion parameters, weirs ############################################
	r.kwe <- exp(theta[ny+24])
	r.tul <- exp(theta[ny+25])
	r.geo <- exp(theta[ny+26])
```

```
        r.kog <- exp(theta[ny+27])
        r.tat <- exp(theta[ny+28])
        r.tak <- exp(theta[ny+29])
### Overdispersion parameters, aerial #################################################
        ra.kwe <- exp(theta[ny+30])
        ra.kis <- exp(theta[ny+31])
        ra.tul <- exp(theta[ny+32])
        ra.sla <- exp(theta[ny+33])
        ra.kip <- exp(theta[ny+34])
        ra.ank <- exp(theta[ny+35])
        ra.hlk <- exp(theta[ny+36])
        ra.osk <- exp(theta[ny+37])
        ra.hlt <- exp(theta[ny+38])
        ra.che <- exp(theta[ny+39])
        ra.gag <- exp(theta[ny+40])
        ra.pit <- exp(theta[ny+41])
        ra.ber <- exp(theta[ny+42])
        ra.slp <- exp(theta[ny+43])
### Likelihood model ##############################################################
        tfw  <-  rep(0,6)
        tfa  <-  rep(0,14)
        tft  <-  0
        tfc  <-  0
        esc  <-  totrun-likedat[,1]
#### Definie the negative binomial function ###########################################
        nblike <- function(obs,r,est){
        lgamma(obs+r)-lgamma(obs+1)-lgamma(r)+r*log(r/(est+r))+obs*log(est/(est+r))
        }
#### Weir likelihood ##############################################################
        tfw[1]  <-  -sum(nblike(likedat[,5],r.kwe,esc/w.kwe),na.rm=T)
        tfw[2]  <-  -sum(nblike(likedat[,6],r.tul,esc/w.tul),na.rm=T)
        tfw[3]  <-  -sum(nblike(likedat[,7],r.geo,esc/w.geo),na.rm=T)
         tfw[4]  <-  -sum(nblike(likedat[,8],r.kog,esc/w.kog),na.rm=T)
         tfw[5]  <-  -sum(nblike(likedat[,9],r.tat,esc/w.tat),na.rm=T)
        tfw[6]  <-  -sum(nblike(likedat[,10],r.tak,esc/w.tak),na.rm=T)
```

```
#### Aerial likelihood ##############################################################
        tfa[1]  <-  -sum(nblike(likedat[,11],ra.kwe,esc/a.kwe),na.rm=T)
        tfa[2]  <-  -sum(nblike(likedat[,12],ra.kis,esc/a.kis),na.rm=T)
        tfa[3]  <-  -sum(nblike(likedat[,13],ra.tul,esc/a.tul),na.rm=T)
        tfa[4]  <-  -sum(nblike(likedat[,14],ra.sla,esc/a.sla),na.rm=T)
        tfa[5]  <-  -sum(nblike(likedat[,15],ra.kip,esc/a.kip),na.rm=T)
        tfa[6]  <-  -sum(nblike(likedat[,16],ra.ank,esc/a.ank),na.rm=T)
        tfa[7]  <-  -sum(nblike(likedat[,17],ra.hlk,esc/a.hlk),na.rm=T)
        tfa[8]  <-  -sum(nblike(likedat[,18],ra.osk,esc/a.osk),na.rm=T)
        tfa[9]  <-  -sum(nblike(likedat[,19],ra.hlt,esc/a.hlt),na.rm=T)
        tfa[10]  <-  -sum(nblike(likedat[,20],ra.che,esc/a.che),na.rm=T)
        tfa[11]  <-  -sum(nblike(likedat[,21],ra.gag,esc/a.gag),na.rm=T)
        tfa[12]  <-  -sum(nblike(likedat[,22],ra.pit,esc/a.pit),na.rm=T)
        tfa[13]  <-  -sum(nblike(likedat[,23],ra.ber,esc/a.ber),na.rm=T)
        tfa[14]  <-  -sum(nblike(likedat[,24],ra.slp,esc/a.slp),na.rm=T)
#### Inriver normal likelihood #######################################################
        tft  <-  0.5*sum((likedat[,2]-totrun)^2/(likedat[,3])^2,na.rm=T)
#### Weekly Catch likelihood, calculated estimated run by week ########################
        wk.est <- likedat[,25:30]*totrun
#### Calculate likelihoood for unrestricted############################################
# Extract all mesh regulation year/week
        unr <- likedat[,43:48]
# Keep unrestricted mesh regulation year/week 1: indicate unrestricted period
        unr[unr != 1] <- NA
# Observed Effort
# Keep only Effort of Unrestricted
        unr.eff <- likedat[,37:42]*unr
# Rmove all NA
        unr.eff <- unr.eff[!is.na(unr.eff)]
# Observed harvest
# Keep only Effort of Unrestricted
        unr.h <- likedat[,31:36]*unr
# Rmove all NA
        unr.h <- unr.h[!is.na(unr.h)]
# Estimated
```

```
# Keep only Effort of Unrestricted
        unr.wk <- wk.est*unr
# Rmove all NA
        unr.wk <- unr.wk[!is.na(unr.wk)]
# likelihood for Unrestricted
  tf1 <- 0.5*length(unr.eff)*log(sum((log(unr.eff)-log(-log(1-unr.h/unr.wk)/q1))^2,na.rm=T))

#### Calculate likelihood for restricted ###############################################
# Extract restricted mesh period
# Extract all mesh regulation year/week
        r <- likedat[,43:48]
# Keep unrestricted mesh regulation year/week 2: indicate restricted periods
        r[r != 2] <- NA
# Change it to 1
        r[r == 2] <- 1
# Observed effort
# Keep only Effort of Restricted
        r.eff <- likedat[,37:42]*r
# Rmove all NA
        r.eff <- r.eff[!is.na(r.eff)]
# Observed harvest
# Keep only Effort of Restricted
        r.h <- likedat[,31:36]*r
# Rmove all NA
        r.h <- r.h[!is.na(r.h)]
# Estimated
# Keep only Effort of Unrestricted
        r.wk <- wk.est*r
# Rmove all NA
        r.wk <- r.wk[!is.na(r.wk)]
# likelihood for Unrestricted
  tf2 <- 0.5*length(r.eff)*log(sum((log(r.eff)-log(-log(1-r.h/r.wk)/q2))^2,na.rm=T))
#### Calculate likelihood for Monofilament############################################
# Extract Monfilament periods
# Extract all mesh regulation year/week (This is taking only 3-6 weeks
```

```
        m <- likedat[,43:48]
# Keep monofilament mesh regulation year/week 3: indicate monofilament peiriods
        m[(m != 3)&(m != 5)] <- NA
# Change it to 1
        m[!is.na(m)] <- 1
# Observed effort
# Keep only Effort of Restricted
        m.eff <- likedat[,37:42]*m
# Rmove all NA
        m.eff <- m.eff[!is.na(m.eff)]
# Observed harvest
# Keep only Effort of Restricted
        m.h <- likedat[,31:36]*m
# Rmove all NA
        m.h <- m.h[!is.na(m.h)]
# Estimated
# Keep only Effort of Restricted
        m.wk <- wk.est*m
# Rmove all NA
        m.wk <- m.wk[!is.na(m.wk)]

  tf3 <- 0.5*length(m.eff)*log(sum((log(m.eff)-log(-log(1-
ifelse(m.h/m.wk<1,m.h/m.wk,0.999))/q3))^2,na.rm=T))
tfc <-sum(tf1,tf2,tf3)

#### Likelihood calculation ##########################################################
loglink  <- sum(sum(tfw),sum(tfa),tft,tfc,na.rm=T)
return(loglink)
}
#### 3.1 Set Initial value and boundaries ##############################################
# Initial starting point
        init <- c(rep(log(250000),ny),rep(5,6),rep(4,14),rep(-10,3),rep(2,6),rep(2,14))
# Lower bounds
        lb <-  c(log(minrun),rep(2,6), rep(3,14),rep(-14,3),rep(-3,6),rep(-3,14))
# Upper bounds
```

```
ub <-  c(rep(log(500000),ny),rep(7,6),rep(8,14),rep(-5,3),rep(5,6),rep(5,14))
#### 3.3 Run likelihood model######################################################
ptm <- proc.time()
nll <- optim(par=init,fn=nb.likelihood,method="L-BFGS-B",lower=lb, upper = ub, control = list(maxit=1000),likedat=kusko.like.data, ny=ny, hessian = T)
min_NLL <- nll$value
proc.time() - ptm
nll$convergence
Rprof()
nll$par
nll$value
#### 3.4  Calculate Wald Confidence Interval ##########################################
#1: Hessian Matrix
    hessian_obs <- nll$hessian
    log_est_obs <- nll$par
    est_obs <- exp(log_est_obs)
# Create a variance-covariance matrix
    var_covar_mat_obs <- solve(hessian_obs)
# Pull out diagonal
    log_var_obs <- diag(var_covar_mat_obs)
# Calculate standard error
    log_std_err_obs <- sqrt(log_var_obs)
    upper95CI <- exp(log_est_obs + 1.96*log_std_err_obs)
    lower95CI <- exp(log_est_obs - 1.96*log_std_err_obs)
    labelT <- length(ny)

for (i in 1:ny){
labelT[i] <- paste('Run',1975+i)
}
labelT <- c(labelT,names(esc),'q1','q2','q3',names(esc))
output <- data.frame(parameter=labelT,mean=exp(nll$par),lower95CI=lower95CI,lower95CI=upper95CI)
```

APPENDIX C: MODEL INPUT DATA

Appendix C1.–Independent estimates of Kuskokwim River Chinook salmon abundance used to scale the run reconstruction model.

Var name:		In.river	In.river.sd
Conventional name:	Year	total run	standard error
	2003	241,617	36,605
	2004	422,657	71,241
	2005	345,814	46,672
	2006	396,248	62,850
	2007	266,219	32,950

Appendix C2.–Harvest of Kuskokwim River Chinook salmon.

Var name:		H.Com	H.Sub	H.Sports	H.Test
Conventional name:	Year	Commercial	Subsistence	Sport	Testfish
	1976	30,735	58,606		1,206
	1977	35,830	56,580	33	1,264
	1978	45,641	36,270	116	1,445
	1979	38,966	56,283	74	979
	1980	35,881	59,892	162	1,033
	1981	47,663	61,329	189	1,218
	1982	48,234	58,018	207	542
	1983	33,174	47,412	420	1,139
	1984	31,742	56,930	273	231
	1985	37,889	43,874	85	79
	1986	19,414	51,019	49	130
	1987	36,179	67,325	355	384
	1988	55,716	70,943	528	576
	1989	43,217	81,175	1,218	543
	1990	53,502	109,778	394	512
	1991	37,778	74,820	401	149
	1992	46,872	82,654	367	1,380
	1993	8,735	87,674	587	2,515
	1994	16,211	103,343	1,139	1,937
	1995	30,846	102,110	541	1,421
	1996	7,419	96,413	1,432	247
	1997	10,441	79,381	1,227	332
	1998	17,359	81,213	1,434	210
	1999	4,705	72,775	252	98
	2000	444	67,620	105	64
	2001	90	78,009	290	86
	2002	72	80,982	319	288
	2003	158	67,134	401	409
	2004	2,305	96,788	857	691
	2005	4,784	85,090	572	557
	2006	2,777	90,085	444	352
	2007	179	96,155	1,478	305
	2008	8,865	98,103	708	420
	2009	6,664	78,231	904	470
	2010	2,732	66,056	354	292
	2011	747	62,368	579	337
	2012	627	22,544	0	321
	2013	174	47,113	0	201
	2014	35	11,234	0	497
	2015	8	16,124	0	472
	2016	0	30,676	0	522
	2017	0	16,380	0	290

Appendix C3.–Weir escapement counts of Kuskokwim River Chinook salmon.

Var name:		w.kwe	w.tul	w.geo	w.kog	w.tat	w.tak
Conventional name:	Year	Kwethluk	Tuluksak	George	Kogrukluk	Tatlawiksuk	Takotna
	1976				5,638		
	1977						
	1978				14,533		
	1979				11,393		
	1980						
	1981				16,089		
	1982				13,126		
	1983						
	1984				4,922		
	1985				4,442		
	1986						
	1987						
	1988				8,028		
	1989						
	1990				10,093		
	1991		697		6,835		
	1992	9,675	1,083		6,563		
	1993		2,218		12,377		
	1994		2,918				
	1995				20,662		
	1996			7,770	13,771		423
	1997			7,810	13,190		1,197
	1998						
	1999				5,543	1,484	
	2000	3,547		2,959	3,242	807	345
	2001		997	3,277	7,475	1,978	718
	2002	8,502	1,346	2,443	10,025	2,237	316
	2003	14,474	1,064		12,008		390
	2004	28,605	1,475	5,488	19,819	2,833	461
	2005		2,653	3,845	21,819	2,864	499
	2006	17,619	1,043	4,355	20,205	1,700	541
	2007	12,927	374	4,011		2,032	412
	2008	5,276	701	2,563	9,750	1,075	413
	2009	5,744	362	3,663	9,528	1,071	311
	2010	1,667	201	1,498	5,812	546	181
	2011	4,079	288	1,547	6,731	992	136
	2012		555	2,201		1,116	228
	2013	845	193	1,292	1,819	495	97
	2014	3,187	320	2,993	3,732	1,904	
	2015	8,162	711	2,282	8,081	2,104	
	2016	6,305[a]	974	1,663	7,056	2,494	
	2017	7,429	646	3,685	9,992	2,156	301

[a] Revised estimate was provided by USFWS on February 15, 2018.

Appendix C4.–Peak aerial survey index counts of Kuskokwim River Chinook salmon.

Var name:		a.kwe	a.kis	a.tul	a.sla	a.kip	a.ank	a.hlk	a.osk	a.hlt	a.che	a.gag	a.pit	a.ber	a.slp
Conventional name:	Year	Kwethluk	Kisaralik	Tuluksak	Salmo (Aniak	Kipchuk	Aniak	Holokuk	Oskawalik	Holitna	Cheeneetnuk	Gagaryah	Pitka	Bear	Salmon (Pitka)
	1976									2,571				182	
	1977	2,075		424							2,407	897			1,930
	1978	1,722	2,417		289					2,766	268	504		227	1,100
	1979														682
	1980			975	1,186										
	1981						9,074							93	
	1982		81		126					521				127	413
	1983	471		186	231		1,909			1,069	173				572
	1984										1,177				545
	1985		63	142							1,002				620
	1986				336		424			650					
	1987				516	193			193		317				
	1988	622	869	195	244		954		80						474
	1989	1,157	152		631	1,598	2,109								452
	1990		631	200	596	537	1,255		113						
	1991		217	358	583	885	1,564								
	1992				335	670	2,284		91	2,022	1,050	328			2,536
	1993				1,082	1,248	2,687	233	103	1,573	678	419			1,010
	1994		1,243		1,218	1,520					1,206	807			1,010
	1995		1,243		1,446	1,215	3,171		326	1,887	1,565		1,193		1,911
	1996				985										
	1997		439		980	855	2,187		1,470	2,093	345	364			
	1998		457		425	443	1,930								
	1999								98	741					
	2000				238	182	714			301			151		362
	2001				598			52		4,156		143		175	1,033
	2002	1,795	1,727		1,236	1,615		513	295	733	730	452[a]	165	211	1,255[b]
	2003	2,661	654	94	1,242	1,493	3,514	1,096	844		810	1,095[b]	197	176	1,242[a]
	2004	6,801	5,157	1,196	2,177	1,868	5,362	539	293	4,051	918	670	290	206	1,138

-continued-

Appendix C4.–Page 2 of 2.

Var name:		a.kwe	a.kis	a.tul	a.sla	a.kip	a.ank	a.hlk	a.osk	a.hlt	a.che	a.gag	a.pit	a.ber	a.slp
Conventional name:	Year	Kwethluk	Kisaralik	Tuluksak	Salmon (Aniak)	Kipchuk	Aniak	Holokuk	Oskawalik	Holitna	Cheeneetnuk	Gagaryah	Pitka	Bear	Salmon (Pitka)
	2005	5,059	2,206	672	4,097	1,679		510	582	1,760	1,155[a]	788[a]	744	367	1,801
	2006		4,734			1,618	5,639	705	386	1,866	1,015	531	170	347	862
	2007		692	173	1,458	2,147	3,984					1,035	131	165	943
	2008	487	1,074		589	1,061	3,222	418	213		290	177	242[b]	245	1,033
	2009							565	379		323	303	187	209	632
	2010		235					229		587[a]		62	67	75	135
	2011				79	116		61	26		249	96	85	145	767
	2012		588		49	193		36	51		229	178			670
	2013	1,165	599	83	154	261	754		38	532	138	74		64	469
	2014		622		497	1,220	3,201	80	200		340	359			1,865
	2015		709		810	917		77		662					2,016
	2016		622			898	718	100	47	1,157	217	135		580	1,578
	2017				423	889	1,781	140	136	676	660	453	234	492	687

Note: Only surveys rated "good" or "fair" were used. Only surveys flown between July 17 and August 5, inclusive, were used. Chinook salmon live and carcass counts were combined.

[a] Survey data added to database in 2017.

[b] Data correction made to database in 2017.

Appendix C5.–Proportion of total annual Chinook salmon run in District W-1 by week, as estimated by Bethel test fishery.

Var name:		rpw.3	rpw.4	rpw.5	rpw.6	rpw.7	rpw.8	rpw.9	rpw.10
Conventional name:	Year	6/10–6/16	6/17–6/23	6/24–6/30	7/1–7/7	7/8–7/14	7/15–7/21	7/22–7/28	7/29–8/26
	1976								
	1977								
	1978								
	1979								
	1980								
	1981								
	1982								
	1983								
	1984	0.2243	0.2903	0.1488	0.1633	0.0509	0.0522	0.0090	0.0173
	1985	0.0000	0.0930	0.2427	0.4306	0.1504	0.0247	0.0175	0.0410
	1986	0.1503	0.4039	0.1656	0.1399	0.0488	0.0097	0.0241	0.0000
	1987	0.1988	0.3070	0.2368	0.1137	0.0210	0.0344	0.0130	0.0094
	1988	0.2080	0.3086	0.1786	0.0852	0.0218	0.0419	0.0145	0.0192
	1989	0.1769	0.2780	0.3474	0.0976	0.0258	0.0190	0.0119	0.0112
	1990	0.1434	0.2095	0.3325	0.1492	0.0609	0.0136	0.0266	0.0256
	1991	0.0593	0.2965	0.2942	0.1994	0.0337	0.0430	0.0000	0.0000
	1992	0.3466	0.1791	0.2132	0.1085	0.0542	0.0554	0.0000	0.0118
	1993	0.2148	0.4172	0.1270	0.0328	0.0273	0.0097	0.0000	0.0000
	1994	0.2883	0.3098	0.1396	0.1009	0.0138	0.0122	0.0000	0.0061
	1995	0.1566	0.3066	0.3005	0.0988	0.0300	0.0050	0.0097	0.0050
	1996	0.4007	0.2138	0.0963	0.0288	0.0214	0.0000	0.0066	0.0033
	1997	0.1913	0.5295	0.1196	0.0533	0.0357	0.0119	0.0079	0.0059
	1998	0.1166	0.2199	0.3866	0.1513	0.0378	0.0116	0.0055	0.0000
	1999	0.1360	0.1349	0.2469	0.1462	0.1903	0.0297	0.0754	0.0297
	2000	0.2089	0.3896	0.1530	0.0461	0.0205	0.0410	0.0000	0.0183
	2001	0.0791	0.4157	0.2510	0.1036	0.0528	0.0367	0.0000	0.0156
	2002	0.3547	0.2245	0.1601	0.1034	0.0337	0.0137	0.0089	0.0132
	2003	0.2764	0.2748	0.1433	0.0662	0.0351	0.0255	0.0112	0.0042
	2004	0.2130	0.2927	0.2513	0.0693	0.0406	0.0537	0.0160	0.0021
	2005	0.2335	0.2851	0.1876	0.1601	0.0768	0.0062	0.0000	0.0168
	2006	0.1299	0.3054	0.2935	0.1675	0.0535	0.0114	0.0142	0.0105
	2007	0.0996	0.2000	0.3114	0.2472	0.0754	0.0316	0.0095	0.0032
	2008	0.1524	0.2931	0.3057	0.1183	0.0431	0.0334	0.0083	0.0139
	2009	0.1955	0.2830	0.3460	0.0753	0.0323	0.0164	0.0000	0.0049
	2010	0.2190	0.3755	0.1517	0.1335	0.0556	0.0185	0.0113	0.0103
	2011	0.1188	0.2976	0.1996	0.1695	0.0818	0.0130	0.0000	0.0031
	2012	0.0508	0.2964	0.3308	0.2114	0.0627	0.0201	0.0088	0.0127
	2013	0.1681	0.3708	0.2654	0.0963	0.0743	0.0108	0.0000	0.0000
	2014	0.2834	0.2370	0.1217	0.0771	0.0148	0.0146	0.0000	0.0029
	2015	0.1859	0.2292	0.1520	0.1316	0.0625	0.0591	0.0338	0.0238
	2016	0.1696	0.1830	0.2085	0.1385	0.0722	0.0296	0.0197	0.0112
	2017	0.0899	0.2067	0.3202	0.1459	0.1117	0.0473	0.0266	0.0265

Appendix C6.–Chinook salmon catch and effort (permit-hours) by week for Kuskokwim River District W-1.

		Week 3 6/10–6/16			Week 4 6/17–6/23		
Var name:		chw.3	cew.3	cfw.3	chw.4	cew.4	cfw.4
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net
	1976	0	0	0	20,010	5,724	1
	1977	12,458	2,802	1	16,227	2,904	1
	1978	18,483	3,972	1	10,066	2,004	1
	1979	24,633	6,432	1	5,651	3,012	2
	1980	9,891	2,814	1	21,698	5,364	4
	1981	29,882	6,180	1	3,830	3,066	2
	1982	4,912	2,784	1	24,628	5,970	1
	1983	13,406	5,634	1	8,063	5,544	2
	1984	0	0	0	17,181	5,562	1
	1985	0	0	0	6,519	2,538	3
	1986	0	0	0	0	0	0
	1987	0	0	0	19,126	4,734	3
	1988	12,640	4,816	3	11,708	3,672	3
	1989	0	0	0	15,215	5,208	3
	1990	0	0	0	16,690	3,780	3
	1991	0	0	0	13,813	3,606	3
	1992	0	0	0	24,334	9,488	3
	1993	0	0	0	0	0	0
	1994	0	0	0	0	0	0
	1995	0	0	0	6,895	2,276	3
	1996	0	0	0	4,091	1,056	3
	1997	0	0	0	10,023	2,118	3
	1998	0	0	0	0	0	0
	1999	0	0	0	0	0	0
	2000	0	0	0	0	0	0
	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	0	0	0	0
	2004	0	0	0	0	0	0
	2005	0	0	0	0	0	0
	2006	0	0	0	0	0	0
	2007	0	0	0	0	0	0
	2008	0	0	0	6,415	1,026	3
	2009	0	0	0	3,003	668	3
	2010	0	0	0	0	0	0
	2011	0	0	0	0	0	0
	2012	0	0	0	0	0	0
	2013	0	0	0	0	0	0
	2014	0	0	0	0	0	0
	2015	0	0	0	0	0	0
	2016	0	0	0	0	0	0
	2017	0	0	0	0	0	0

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		Week 5 6/24–6/30			Week 6 7/1–7/7		
Var name:		chw.5	cew.5	cfw.5	chw.6	cew.6	cfw.6
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net
	1976	4,143	2,088	2	1,550	2,490	2
	1977	1,841	4,722	2	673	4,194	2
	1978	3,723	5,346	2	2,354	8,676	2
	1979	3,860	6,438	2	1,233	3,252	2
	1980	1,460	2,448	2	498	2,298	2
	1981	4,563	5,952	2	2,795	5,520	2
	1982	12,555	5,176	4	1,970	3,968	2
	1983	4,925	5,958	2	2,415	5,634	2
	1984	5,643	5,616	2	3,206	5,454	2
	1985	19,204	5,880	3	9,942	5,844	3
	1986	11,986	6,540	3	5,029	6,852	3
	1987	0	0	0	9,606	6,948	3
	1988	15,060	7,518	3	5,871	6,954	3
	1989	11,094	6,144	3	7,911	7,092	3
	1990	25,459	7,536	3	4,071	3,546	3
	1991	12,612	3,696	3	8,068	7,308	3
	1992	16,307	8,628	3	3,250	4,696	3
	1993	8,184	4,976	3	0	0	0
	1994	14,221	4,608	3	0	0	0
	1995	14,424	4,532	3	4,368	3,824	3
	1996	666	360	3	861	836	3
	1997	0	0	0	0	0	0
	1998	12,771	4,584	3	2,277	1,780	3
	1999	4,668	2,454	3	0	0	0
	2000	0	0	0	357	896	3
	2001	0	0	0	0	0	0
	2002	0	0	0	0	0	0
	2003	0	0	0	0	0	0
	2004	520	104	3	1,107	446	3
	2005	3,531	1,189	3	874	604	3
	2006	2,493	1,038	3	0	0	0
	2007	0	0	0	0	0	0
	2008	2,362	783	3	19	4	3
	2009	2,539	752	3	762	519	3
	2010	1,724	1,324	5	290	522	3
	2011	0	0	0	361	634	5
	2012	0	0	0	0	0	0
	2013	0	0	0	0	0	0
	2014	0	0	0	0	0	0
	2015	0	0	0	0	0	0
	2016	0	0	0	0	0	0
	2017	0	0	0	0	0	0

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		Week 7 7/8–7/14			Week 8 7/15–7/21			Week 9 7/22–7/28		
Var name:		chw.7	cew.7	cfw.7	chw.8	cew.8	cfw.8	chw.9	cew.9	cfw.9
Conventional name:	Year	Catch	Effort	Net	Catch	Effort	Net	Catch	Effort	Net
	1976	1,238	4,548	2	236	1,590	2	0	0	0
	1977	153	2,310	2	0	0	0	0	0	0
	1978	987	7,668	2	0	0	0	0	0	0
	1979	470	3,120	2	0	0	0	0	0	0
	1980	445	2,586	2	0	0	0	0	0	0
	1981	941	2,640	2	0	0	0	0	0	0
	1982	1,055	4,734	2	0	0	0	0	0	0
	1983	633	2,796	2	0	0	0	0	0	0
	1984	2,069	5,592	2	744	2,238	2	0	0	0
	1985	0	0	0	0	0	0	0	0	0
	1986	1,156	3,192	3	0	0	0	0	0	0
	1987	1,910	3,582	3	2,758	6,720	3	0	0	0
	1988	5,270	10,794	3	1,728	6,636	3	662	6,276	3
	1989	6,043	10,962	3	868	2,622	3	210	3,372	3
	1990	4,931	8,534	3	0	0	0	0	0	0
	1991	904	3,426	3	452	3,408	3	419	7,522	3
	1992	0	0	0	0	0	0	0	0	0
	1993	0	0	0	0	0	0	0	0	0
	1994	578	1,984	3	441	3,000	3	538	6,348	3
	1995	1,452	3,716	3	568	3,488	3	0	0	0
	1996	408	896	3	251	1,195	3	307	6,398	3
	1997	0	0	0	0	0	0	0	0	0
	1998	1,127	1,668	3	0	0	0	816	4,296	3
	1999	0	0	0	0	0	0	0	0	0
	2000	0	0	0	0	0	0	0	0	0
	2001	0	0	0	0	0	0	0	0	0
	2002	0	0	0	0	0	0	0	0	0
	2003	0	0	0	0	0	0	0	0	0
	2004	0	0	0	0	0	0	127	360	3
	2005	0	0	0	0	0	0	0	0	0
	2006	0	0	0	0	0	0	0	0	0
	2007	0	0	0	0	0	0	0	0	0
	2008	1	6	3	0	6	0	0	12	0
	2009	113	436	3	83	672	3	58	752	3
	2010	271	686	3	186	958	3	176	1,632	3
	2011	227	996	5	129	1,226	5	24	1,668	5
	2012	45	604	5	195	1,616	5	39	1,464	5
	2013	0	0	0	139	2,018	5	21	1,556	5
	2014	14	584	5	14	2,276	5	0	0	0
	2015	0	0	0	0	0	0	0	0	0
	2016	0	0	0	0	0	0	0	0	0
	2017	0	0	0	0	0	0	0	0	0